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REVIEWS.

Om klimatets ändringar i geologisk och historisk tid samt deras orsaker. [On Changes of Climate in Geologic and Historic Time and their Causes.] By NILS EKHOLM, *Ymer*, Årg. 1899, H. 4, pp. 353–403. Published by Svenska Sällskapet för anthropologi och geografi, Stockholm.

The first section of the paper discusses, in a general way, the causes of telluric temperature changes. The author states at the outset that the temperature of the earth depends upon the ratio of the amounts of insolation and radiation. He thinks that the solar radiation has very likely not been subject to any considerable changes during the time the earth has been an abode of life. But the transparency of the atmosphere to different kinds of heat rays, and hence also to radiation, has, no doubt, varied greatly and caused the great changes in climate known to geology. Only in the second place would he put the eccentricity of the earth's orbit and the inclination of its axis as a cause of climatic changes. He does not think that the eccentricity of the earth's orbit has caused any climatic variations which have left traces known to geologists. But the variations in the inclination of the earth's axis have caused changes of considerable magnitude in the polar regions, and in the adjacent zone, at least as far down as the latitude of 55° in the northern hemisphere.

The old notion that the internal heat of the earth has appreciably affected climatic conditions in geological time must be set aside. The earth was, no doubt, at one time in the same condition in which we now find the planet Jupiter. There was a dense atmosphere filled with steam. After the temperature of this atmosphere of the cooling globe sank below the boiling point of water its vapor rapidly (in a few hundred years) condensed to a boiling sea. While the convection of this sea was in effective action, the temperature of the sea bottom, the upper crust of the earth, was rapidly lowered, which caused the outer crust to crack open as it contracted relatively more rapidly than the interior. This process went on until the radiation of the crust outward (which grew less and less) equaled the conduction from below. Then there was a resting time. The cracking ceased. Later the conduction of heat from the interior to the crust was smaller in amount than the radiation from the surface. As a result lateral pressure was developed and caused the rise of the land above the sea here and there in folds.

The paper then proceeds to offer proof that the conduction from the heated interior is vanishingly small at present compared with insolation, hence it can cause no appreciable rise in temperature now.

There follow some paragraphs on geological time and the probable age of life on the earth. The author quotes some computations "made by T. Mellard Reade and communicated by Chamberlin" relative to the age of the sea (JOURNAL OF GEOLOGY, Vol. VIII, p. 572). The computations referred to were made by Chamberlin, though this is not explicitly stated in the paper quoted. The estimates made by Nathorst, Phillips, and Geikie are given. The calculations of Lord Kelvin are also discussed. He is said to have made use of such assumptions that the results attained can hardly be regarded as anything more than a mathematical exercise without bearing on the physical problems involved. It is maintained that there are no physical data disproving the high estimates of geological time favored by geologists and biologists.

The headings of the third part of the paper may be rendered as follows: Insolation nearly constant during geological time; changes in the quantity of carbon dioxide in the atmosphere the principal cause of the great climatic changes; the cause of the change in the quantity of carbon dioxide in the atmosphere. The author refers to Lord Kelvin as having made calculations on radiation from the sun, and having reached the conclusion that the mean temperature of the sun has been constantly rising. The author has carried out further these computations in a paper just submitted to Kongliga Svenska Vetenskaps Akademien, entitled *Ueber den Energie-Vorrath, die Temperatur und Strahlung der Weltkörper*, and finds that the rise in the mean temperature of the earth has been compensated by the diminution in the surface of the sun and also by the decreasing efficiency of the convection currents from the interior to the exterior of the sun. Possibly the radiation was less than it is now at the time when the sun's radius was sixty times its present length.

Then follows an account of the researches of Arrhenius. From these some conclusions are drawn. It is estimated that a diminution of the carbonic acid in the atmosphere to two thirds of its present amount would probably reduce the temperature of the polar regions by 5° C., and a tripling of the present amount would increase the temperature there by 18° to 20° C., the temperature of the Cretaceous period. A few paragraphs are devoted to discussing the amount of carbon dioxide, the cause of its fluctuations. Using a commercial simile, he remarks that the exchanges between the CO_2 consuming processes and the CO_2 yielding processes are carried on with a very small capital, and hence they are proportionately rapid, and as a result are subject to great and fortuitous changes. New carbonic acid is furnished by volcanic activities (Chamberlin, JOURNAL OF GEOLOGY, Vol. VI, p. 611), and by meteors bringing it into the upper atmosphere. Pursuing his commercial simile he remarks that the reserve fund is in the sea. Chamberlin is again quoted on the effect of lime-secreting organisms in the sea and as to the chemical condition of the carbonic acid in the sea.

Over the first ocean the atmosphere very likely became, as time went on, more and more impregnated with carbon dioxide. This is supposed to have taken place after the conduction of heat from the earth's interior had ceased to have climatological importance. This increase of carbon dioxide is believed to have resulted in the rise of temperature which affected the crust of the earth. The temperature of the early Cambrian age is hypothetically placed at 20° C., with a rise during the period of 10° higher temperature. It is estimated that this rise of temperature would cause folds four kilometers in height, if the expansion were concentrated so as to have caused rising in any single place. In a similar way mountains are held to have been formed in the Carboniferous age. By erosion large amounts of the carbonates were carried to the sea, favoring the life of carbonate-secreting animals. By the increase of land and of temperature the consumption of CO_2 was increased, resulting in the withdrawal of much of it. Thus the cold of the Permian age was brought on.

The progressive cooling of the surface temperature during the Permian age is also discussed. A change from 30° to 10° C. is assumed. This brought about a contraction of the outer shell relative to the inner kernel of the earth. The computed relative shrinking of the outer shell is 12.8 kilometers. This shrinkage brought on extensive cracking and volcanic activity, and thus led to an increased production of carbon dioxide. Thus warm climate again resulted, probably lasting during the Cretaceous and into the Tertiary period. A subsequent period of folding and withdrawal of carbonic acid resulted in the great ice age. After several less well-known climatic changes—some geologists count as many as six different ice periods—the recent period finally arrived with its temperate climate, in which we still live.

To the fundamental causes here discussed as affecting the climatic changes of long duration, a secondary cause may be added, as pointed out by Chamberlin, namely, the continued erosion and denudation of the continents by precipitation. It is evident that this cause intensifies the climatic conditions between cold and warm periods. In a note (p. 375) the author leaves it to the future to decide whether the interglacial periods are due to changes in the atmosphere, or to changes in the inclination of the earth's axis.

Since the cooling of the polar regions of the earth have, on the whole, always been in advance of the cooling of the tropical and temperate zones, our greatest mountains lie in these latter zones. The polar caps have attained a greater solidity and resistance to pressure, and thus the folding has been mostly transferred to other regions.

The sea has served as a great moderator of the climatic changes of long period. *The cause of the latter must be sought in the alternate contraction and expansion of the earth's crust following changes in the mean temperature of the atmosphere.*

The fourth part of the paper has for its subject *the changes in the inclination of the earth's axis to the ecliptic and its influence on climate.* Here is first given a summary of the evidence of changes in the flora and fauna of northern Sweden, since the ice left the peninsula. Since the time of the "Oak zone," the average temperature has fallen 2° C., judging by the fossil distribution of Hazel. Possibly the winter temperature was but little different from the present. Accepting the archeologist's figures as to the time of the appearance of paleolithic man in Sweden, 7000 to 10,000 years back, the highest temperature of the climate of Sweden seems to have occurred at that time. The author then proceeds to show that the Quaternary changes of climate can be readily and fully accounted for by the "long-periodic" changes in the inclination of the earth's axis. He has tabulated Stockwell's calculations (p. 381). These show the inclination to have been small about 9000 years ago, and that it has been increasing since then. He presents a calculation of the length of the mid-summer day (the sun not setting) for Karesuando, the northernmost meteorological station in Sweden, at the latest minimum and maximum of inclination, respectively 9100 and 28,300 years ago, thus:

28,300 years ago - -	38 days
9,100 years ago - - -	62 days
At present - - -	54 days

Then follow tables showing calculated temperatures (in terms of excess and deficiency compared with the present) for different latitudes during the months of the year at the last maximum (28,300 years ago) and the last minimum of inclination (9100 years ago) north of 80° N. latitude. There was, 28,300 years ago, a deficiency of 5° C. In Sweden the deficiency was from 3½° to 2° C. These figures are all for the summer months. The author is uncertain as to the winter temperatures. In Sweden these would perhaps depend on the gulf stream, as at the present; 9100 years ago the summer heat was 2° to 1.3° C. higher than now, while the winter temperature is uncertain. A time with hot summers occurred 48,000 years ago. Geologists know of no other period of greater heat than the present, except the one 9000 years ago, *since the end of the last glaciation*. The end of the ice age, hence, cannot have occurred earlier than 50,000 years ago. Possibly it is later, but the greater summer insolation 48,000 years ago may have helped in melting the ice.

The last section of the paper relates to *climatological changes in historic time, especially in northwest Europe*. The author discusses recorded observations on the forming and thawing of ice on various Scandinavian waters, ancient stock-raising in Greenland, grape culture, etc., and concludes that the winters have grown milder and the summers cooler during the last 300 years. Some conclusions are drawn from a study of weather records made by Tycho Brahe. A comparative table of snow precipitation for Brahe's time and the present is given as follows.

PER CENT. OF DAYS WITH SNOW OUT OF TOTAL DAYS OF PRECIPITATION.

Years	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1582–1597 (Time of Brahe) -	3	14	38	45	75	63	21
1881–1898 (Present) - -	2	16	37	48	53	46	19

By comparing this table with current temperature, he finds that it is likely that 300 years ago February was 1.4° C. colder than now, March 1° C. colder, and the other months differed either way by less than .2° C.

Finally the author discusses secular temperature changes as indicated by thermometric measurements made in the last 100 or 150 years, and concludes that at Haparanda, Stockholm, and Lund, in Sweden, the January temperature has risen during this time 1° C., while that of August has become somewhat cooler. At Lund, April, June, September, and October temperatures have remained unchanged.

The paper contains five figures. One of these shows the fossil and present distribution of Hazel in Sweden.

This article is particularly interesting to one who has previously read Chamberlin's papers on the same questions. There are several points of coincidence in the two. One of the authors is a meteorologist, the other a geologist, by profession. On the main cause of long-periodic changes of climate both agree. In accounting for minor details the geologist favors meteorologic causes, while the meteorologist seems inclined to accept, with a modification, a hypothesis which has been quite generally favored among geologists.

J. A. UDDEN.

Sveriges temperaturförhållanden jämförda med det öfriga Europas. [The Temperature Conditions of Sweden compared with those of the rest of Europe.] By NILS EKHOLM, *Ymer*, Årg. 1899, H. 3, pp. 221–242. Published by Svenska Sällskapet för antropologi och geografi, Stockholm.

The only portion of this paper that has obvious geological bearing is the statement that the temperature conditions of Sweden, especially the cold winters which sometimes occur, are to be explained rather by exceptional conditions favorable to radiation than by cold winds coming from Siberia. The author shows, among other things, that the recurrence of cold winters in Sweden exhibits a quite definite periodicity of five and two thirds years, or half the length of the sun-spot period.

J. A. UDDEN.

Physiography of the Chattanooga District in Tennessee, Georgia, and Alabama. By C. WILLARD HAYES. United States Geological Survey. Part VII, Annual Report, 1897–8.

In this report the author has done what Gilbert did in his "Geology of the Henry Mountains," namely, has made a study of a region